Federal Aviation Administration – Regulations and Policies
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Engine Harmonization Working Group

**Task 1 -- Bird Ingestion**

# Task Assignment

## DEPARTMENT OF TRANSPORTATION

### Federal Aviation Administration

### Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Subcommittee; Propulsion Harmonization Working Group

**AGENCY:** Federal Aviation Administration (FAA), DOT.

**ACTION:** Notice of establishment of Propulsion Harmonization Working Group.

**SUMMARY:** Notice is given of the establishment of the Propulsion Harmonization Working Group of the Transport Airplane and Engine Subcommittee. This notice informs the public of the activities of the Transport Airplane and Engine Subcommittee of the Aviation Rulemaking Advisory Committee.

**FOR FURTHER INFORMATION CONTACT:** Mr. William J. (Joe) Sullivan, Executive Director, Transport Airplane and Engine Subcommittee, Aircraft Certification Service (AIR–3), 800 Independence Avenue SW., Washington, DC 20591, Telephone: (202) 267–9554; FAX: (202) 267–5364.

**SUPPLEMENTARY INFORMATION:** The Federal Aviation Administration (FAA) established an Aviation Rulemaking Advisory Committee (56 FR 2190, January 22, 1991) which held its first meeting on May 23, 1991 (56 FR 20492, May 3, 1991). The Transport Airplane and Engine Subcommittee was established at that meeting to provide advice and recommendations to the Director, Aircraft Certification Service, FAA, regarding the airworthiness standards for transport airplanes, engines and propellers in parts 25, 33, and 35 of the Federal Aviation Regulations (14 CFR parts 25, 33, and 35).

The FAA announced at the Joint Aviation Authorities (JAA)—Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Ontario, Canada, (June 2–5, 1992) that it would consolidate within the Aviation Rulemaking Advisory Committee structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR). Coincident with that announcement, the FAA assigned to the Transport Airplane and Engine Subcommittee those projects related to JAR/FAR 25, 33, and 35 harmonization which were then in the process of being coordinated between the JAA and the FAA. The harmonization process included the intention to present the results of JAA/FAA coordination to the public in the form of either a Notice of Proposed Rulemaking or an advisory circular—an objective comparable to and compatible with that assigned to the Aviation Rulemaking Advisory Committee. The transport Airplane and Engine Subcommittee, consequently, established the Propulsion Harmonization Working Group.

Specifically, the Working Group's tasks are the following: The Propulsion Harmonization Working Group is charged with making recommendations to the Transport Airplane and Engine Subcommittee concerning the FAA disposition of the following subjects recently coordinated between the JAA and the FAA:

*Task 1—Bird Ingestion:* Update turbine engine bird ingestion requirements, including size and number of birds and pass/fail criteria (FAR 33.77)

*Task 2—Inclement Weather:* Update the inclement weather requirements for rain and hail in turbine engines (FAR 33.77).

*Task 3—Vibration Surveys:* Determine test requirements and pass/Fail criteria for turbine engine vibration tests (FAR 33.83).

*Task 4—Rotor Integrity:* Determine test requirements and pass/fail criteria for turbine, compressor, fan, and turbosupercharger rotor overspeed tests (FAR 33.27).

*Task 5—Turbine Rotor Overtemperature:* Clarify test and pass/fail requirements for turbine engine overtemperature tests to assure consistent certification criteria (FAR 33.88).

*Task 6—Windmilling:* Exmaine current turbine engine windmilling requirements and specify appropriate test and analysis requirements (FAR 33.92).

*Reports:*

A. Recommend time line(s) for completion of each task, including rationale, for Subcommittee consideration at the meeting of the subcommittee held following publication of this notice.

B. Give a detailed conceptual presentation on each task to the Subcommittee before proceeding with the work stated under items C and D, below. If task 1–6 require the development of more than one Notice of Proposed Rulemaking, identify what proposed amendments will be included in each notice.

C. Draft a Notice of Proposed Rulemaking for tasks 1–6 proposing new or revised requirements, a supporting economic analysis, and other required analysis, with any other collateral documents (such as Advisory Circulars) the Working Group determines to be needed.

D. Give a status report on each task at each meeting of the Subcommittee.

The Propulsion Harmonization Working Group will be comprised of experts from those organizations having an interest in the tasks assigned. A working Group member need not necessarily be a representative of one of the organizations of the parent Transport Airplane and Engine Subcommittee or of the full Aviation Rulemaking Advisory Committee. An individual who has expertise in the subject matter and wishes to become a member of the Working Group should *write* the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task, and the expertise he or she would bring to the Working Group. The request will be reviewed with the Subcommittee and Working Group Chairs and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee and its subcommittees are necessary in the public interest in connection with the performance of duties of the FAA by law. Meetings of the full Committee and any subcommittees will be open to the public except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Propulsion Harmonization Working Group will not be open to the public except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of Working Group meetings will be made.

Issued in Washington, DC, on December 4, 1992.

**William J. Sullivan,**

*Executive Director, Transport Airplane and Engine Subcommittee, Aviation Rulemaking Advisory Committee.*

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# Recommendation

**Date: 13 DECEMBER 1996**

**Revision: 11**

**File: birdru11.doc**

**DRAFT NPRM FOR BIRD INGESTION**

[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 33

[Docket No. XXXXX; Notice No. XX-XXX]

RIN NO. XXXX

Airworthiness Standards; Bird Ingestion Standards

AGENCY: Federal Aviation Administration, DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This notice proposes to amend the bird ingestion type certification standards for aircraft turbine engines. This proposal revises the bird ingestion standards to reflect recent analyses defining the actual bird threat encountered in service by turbine engines. This proposal also harmonizes the FAA's type certification standards on this issue with requirements being drafted by the Joint Aviation Authorities (JAA). The proposed changes, if adopted, would establish nearly uniform bird ingestion standards for aircraft turbine engines certified in the United States under 14 CFR part 33 (part 33) and in the JAA countries under Joint Aviation Requirements, simplifying airworthiness approvals for import and export.

DATES: Comments to be submitted on or before [Insert date 90 days after the date of publication in the Federal Register].

ADDRESSES: Comments on this notice should be mailed in triplicate to: Federal Aviation Administration, Office of the Chief Counsel, Attention: Rules Docket (AGC-10), Docket No. , 800 Independence Avenue, SW., Washington, DC 20591. Comments delivered must be

marked Docket No. . Comments may be inspected in Room 915G weekdays between 9:00 a.m. and 5:00 p.m., except on Federal holidays.

FOR FURTHER INFORMATION CONTACT: Marc Bouthillier, Engine and Propeller Standards Staff, ANE-110, Engine and Propeller Directorate, Aircraft Certification Service, FAA, New England Region, 12 New England Executive Park, Burlington, Massachusetts 01803-5299; telephone (617) 238-7120; fax (617) 238-7199.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to submit written data, views, or arguments on this proposed rule. Comments relating to the environmental, energy, federalism, or economic impact that might result from adopting the proposals in this notice are also invited. Substantive comments should be accompanied by cost estimates. Comments should identify the regulatory docket number and should be submitted in triplicate to the Rules Docket address specified above. All comments received on or before the closing date for comments specified will be considered by the Administrator before taking action on this proposed rulemaking. The proposals contained in this notice may be changed in light of comments received. All comments received will be available, both before and after the closing date for comments, in the Rules Docket for examination by interested persons. A report summarizing each substantive public contact with Federal Aviation Administration (FAA) personnel concerned with this rulemaking will be filed in the docket. Commenters wishing the FAA to acknowledge receipt of their comments submitted in response to this notice must include a pre addressed, stamped postcard on which the following statement is made: "Comments to Docket No. ." The postcard will be date stamped and mailed to the commenter.

Availability of NPRMs

Any person may obtain a copy of this NPRM by submitting a request to the Federal Aviation Administration, Office of Public Affairs, Attention: Public Inquiry Center, APA-200,

800 Independence Avenue, SW., Washington, DC 20591, or by calling (202) 267-3484. Communications must identify the Notice Number of this NPRM.

Persons interested in being placed on the mailing list for future NPRMs should request, from the above office, a copy of Advisory Circular No. 11-2A, Notice of Proposed Rulemaking Distribution System, which describes the application procedure.

Background

Statement of the Problem

In 1976 the National Transportation Safety Board (NTSB), in response to an accident involving a wide bodied aircraft that may have experienced multiple bird ingestion into the engines, issued safety recommendation A-76-64, recommending the FAA, "amend 14 CFR 33.77 to increase the maximum number of birds in the various size categories required to be ingested into turbine engines with large inlets". Safety recommendation A-76-64 also stated, "these increased numbers and sizes should be consistent with the birds ingested during service experience of these engines." As a result of this recommendation, the FAA sponsored an industry wide study of the types, sizes, and quantities of birds, and their resulting effects, that had been ingested into aircraft turbine engines of all sizes. Following this data collection period, the FAA requested the Aerospace Industries Association (AIA) to analyze the data and resulting damage to the engines, and to report back to the FAA . Based on that report, the FAA determined the actions to be taken as well as the disposition of the NTSB safety recommendation A-76-64. The FAA found that the regulations then specified as FAR 33.77 should be modified to increase the severity of the bird ingestion testing requirements regarding large high bypass ratio engines. In addition, the FAA found that it should update the design and testing requirements for all engine sizes to reflect the actual numbers and bird sizes being ingested. This effort was adopted as a Federal Aviation Regulation (FAR) Part 33 and Joint Aviation Regulations for engines (JAR-E) harmonization project and was selected as an Aviation Rulemaking Advisory Committee (ARAC) project.

Industry Study

The industry study consisted of FAA sponsored contracts which are summarized in FAA report number DOT/FAA/CT-84/13, dated September 1984. The industry powerplant bird group, consisting of the AIA and AECMA, initially reviewed the historical bird threat and resulting impact to flight safety for a 20 year period through 1987. The data collected represented a cross-section of large high bypass turbofan engines in service during that time period. After collection and review of the available data, an analysis was performed to characterize both the environmental threat (sizes, quantities and occurrence rates) and consequences. The results of this initial data analysis were presented to the FAA in AIA reports dated October 17, 1986 and November 10, 1988. The results of the analysis were compared to the historical design standards and certification bases for the family of engines comprised in the data base. Subsequent to the above described data collection and analysis, additional data was collected and analyzed for small and medium sized turbine engines which were not represented within the initial database. This data is contained within FAA Technical Center reports dated December 1990 & 1991, and July 1992. The above described data were combined to form the basis for this proposed rule.

As a result of that analysis, the industry study group identified bird encounter threats more severe than were addressed in either engine design practices of the time, or in the part 33 regulations.

In addition to the industry study/data analysis for large engines, industry also addressed the service experience of the small turbojet/turbofan designs. With the rapid expansion of the turbojet/turbofan powered business jet fleet in the late 1960's and early 1970's, a significant number of multiple engine power loss accidents due to flocking bird ingestion occurred. Careful review of these turbojet/turbofan events showed that the flight crews had often flown through very large flocks of birds with ingestion of many birds in each engine which resulted in multiple engine flameouts.

Following discussion with the manufacturers which showed that mechanical design changes would not alleviate the adverse effects of severe inlet blockage caused by massive

flocking bird ingestions, the FAA and the manufacturers embarked upon an educational/publicity campaign to better inform the aviation community regarding bird hazards and necessary controls. Subsequent to implementation of this educational campaign in late 1976, there was a marked decrease in the accident rate. Additionally, after the introduction of bird ingestion requirements in part 33, Amendment 6 on October 31, 1974, manufacturers were required to incorporate significant design improvements to address the typical flocking bird threat. Service experience of business jet engine designs that have met the Amendment 6 standard indicate that their resistance to bird ingestion induced damage is greatly improved over that early service history.

ARAC Project

The FAA is committed to undertaking and supporting the harmonization of the FAR Part 33 with the JAR-E. In August 1989, as a result of that commitment, the FAA Engine and Propeller Directorate participated in a meeting with the Joint Aviation Authorities (JAA), AIA, and the Association Europeenne Des Constructeurs De Material Aerospatial (AECMA). The purpose of the meeting was to establish a philosophy, guidelines, and a working relationship regarding the resolution of issues identified as needing to be harmonized, including some where new standards are needed. All parties agreed to work in a partnership to jointly address the harmonization effort task. This partnership was later expanded to include the airworthiness authority of Canada, Transport Canada.

This partnership identified seven items which were considered the most critical to the initial harmonization effort. The new proposed bird ingestion standards are an item on this list of seven items, and, therefore, represent a critical harmonization effort.

This proposal has been selected as an ARAC project. The issues were assigned to the Engine ~~Propulsion~~ Harmonization Working Group of the Transport Airplane and Engine Issues Group (TAEIG) on December 11, 1992 (57 FR 58840). On XXXX XX, 199X, the TAEIG recommended to the FAA that it proceed with the rulemaking and associated advisory material even though one airworthiness authority expressed disagreement with the proposed rule. This NPRM and associated advisory material reflect the ARAC recommendations.

Therefore, the basis for the development of this revised rule is to (1) minimize the threat to the aircraft for the above noted historical bird threat to one or more engines; and (2) substantiate that the engine design provides at least a 1E-8 per aircraft cycle freedom from risk of a hazardous consequence to the aircraft due to the bird ingestion threat For all bird ingestion threats, a hazardous consequence occurs when the resulting damage results in an unsafe condition as defined in Section 33.75; and in the specific case of small and medium birds, where insufficient power is retained to provide safe flight and landing.

The medium bird ingestion criteria for small engines were established consistent with corresponding criteria for medium and large engines which is freedom from multi-engine power loss events at a rate of 1E-8 per aircraft cycle. These criteria are based on the assumption that current standards for airport certification will be maintained, that the historical environment will not worsen, and that airport operators and pilots will maintain at least their current awareness of the threat.

The development of the rule recognizes that the engine design must address the threat without regard to past successes as shown in the service history data base. Unless the rule addresses the actual in-service bird ingestion threat, there can be no assurance that future designs would continue to exhibit acceptable capability.

The results of this data analysis are summarized as follows:

1. Dual engine power loss events with hazardous consequences (flocking birds of all sizes) have occurred at the rate of 3.2E-7 occurrences per aircraft cycle for large high-bypass ratio engines. This finding reflects service data for the 20 year period through 1987.

2. Multiple engine ingestion of flocking birds up to 2.5 pounds has occurred at the rate of 1E-6 occurrences per aircraft cycle for large high-bypass ratio engines.

3. Single engine power loss events due to ingestion of birds smaller than the current section 33.77 standard has occurred at a rate of 1E-6 or greater per aircraft cycle for all large high-bypass ratio engines.

4. Single engine ingestion of a large bird (4-8 lb. based on inlet area) has occurred at a rate up to 3.1E-6 occurrences per aircraft cycle.

5. Dual engine ingestion of flocking birds up to 1.5 pounds has occurred at a rate of 1E-8 occurrences per aircraft cycle for small engines.

6. Bird ingestion service difficulty issues relating to engine models not type certificated to the new proposed requirements, can safely be addressed by continued airworthiness control programs.

Recognition was also given to the need to design a conservative test, while at the same time being representative of in-service combinations of critical ingestion parameters It was recognized that it was impractical to test all possible combinations of events, but that a degree of conservatism was called for in a single test demonstration. Conservatism was incorporated into the test by selecting bird sizes or quantities, or both, among the most severe encountered within the 1E-8 service history, as well as requiring critical test parameters to be at worse case combination (speeds and aim points). It is therefore considered reasonable to accept a satisfactory test outcome which is conservative with respect to the various combinations of critical test parameters, and their demonstrated rate of occurrence in service.

An example of parametric rule consideration during regulatory tests is the question of multiple bird impacts to the same blade. The likelihood of multiple impacts on one blade is dependent on the number of birds, the number of blades, and the exposed frontal area. The manufacturers have stated that it is not always possible to achieve a uniform distribution of birds across the complete face of the engine in a single engine test. This may result in multiple birds striking the same blade. This may be viewed as unrepresentative and overly conservative based on probabilities appropriate to a random ingestion (averaged over a multiple ingestion event).

With respect to the flocking bird threat, the applicant needs to consider the potential effects on the engine associated with the size and number of birds, and operating conditions of a typical aircraft. For smaller flocking birds (0.5-1.5 lb.), greater quantities of birds may be ingested compared to quantities associated with larger size flocking birds. Both the effects of

bird size on the impact loading of the engine components, as well as the quantity ingested with potential multiple target locations being struck on the face of the engine, must be considered. Additionally, the applicant must consider the potential effects of the ingestion and the resultant damage effects to the front face of the engine as well as the core to the engine's run-on capability.

Analysis of the service record of engines larger than 2000 square inches over a 20 year period has lead to the conclusion that some additional certification standards are required. The proposed standards are intended to reduce the risk of a dual engine power loss from current in-service rates. The improvement goal is approximately 1E-8 or better per aircraft departure. The data analysis has identified specific flocking bird threats up to approximately 8 pound size (Canada goose). Therefore, it is the intent of this proposed rule to strengthen the engine airworthiness requirements by increasing the medium bird ingestion requirements from 1.5 lb. to 2.5 lb. birds (representing the herring gull threat); and by increasing the single large bird ingestion requirements to address bird threats from 4 lb. up to 8 lb. (Canada goose).

It is recognized that flocking birds larger than those specified in this rule may be encountered. It is believed that available engine technology alone cannot economically provide mitigation of this risk to approximately E-8 or better per aircraft departure. However, mitigation of this threat may be provided by the more severe conditions of the medium flocking and single large bird requirements proposed herein (i.e., bird size and number, run on requirement, etc.), introduction of aircraft that can be operated with up to a 50 percent power loss from each engine (large twin engine transport aircraft), and improved airport bird control methods and awareness.

The data summary supporting this conclusion for medium to large high bypass engines (70-100 inch inlet diameter except as noted) is as follows:

Multiple engine ingestions of birds greater than 1.0 lb. = 2.1E-6*

Multiple engine ingestions of birds greater than 1.5 lb. = 1.4E-6*

Multiple engine ingestions of birds greater than 2.5 lb. = 1.4E-7**

Multiple engine ingestions of birds greater than 4.0 lb. = 8.8E-8**

Multiple engine ingestions of birds greater than 2.5 lb. = 9.5E-8***

*Data collection period 1970-1987

**Data collection period 1970-1995

***Data collection period 1970-1995 for 60-100 in diameter inlets

It was also noted that the number of birds likely to be ingested into all engines during a flock encounter was inversely proportional to the size of birds. These were examined on an exceedence basis; i.e., 95% of the time no more than the following quantities of birds would be ingested into all of the engines on an aircraft during a flock encounter. As an example of this the following quantities of birds ingested for engines in the 6000 square inch class are as follows:

For birds in the 1.0-1.5 lb. species: 3 birds

For birds in the 1.5-2.5 lb. species: 3 birds

For birds greater than 2.5 lb.: 2 birds

In consideration of the desire to evaluate multiple critical target locations on the face of the engine, it was decided to select a size of flocking bird that corresponded to a bird quantity of 2 or more birds. However, it is recognized that there would be a residual risk of encounter of potentially larger bird sizes than specified in the rule, and possibly greater quantities of birds than specified in the rule. This proposed rule change significantly increases the severity of the certification demonstration, and provides a reduction in risk of a dual engine power loss due to flocking bird ingestion.

In considering single large bird threats for sizes greater than that demonstrated under the medium flocking bird threat to multiple engines, the data analysis attempted to quantify exposure rates for birds weighing 4 pounds and up as a function of inlet threat area. Data from FAA Technical Center reports from 1990 through 1992 were used in addition to the original AIA studies.

The data showed that small and medium engine sizes up to an inlet throat area of 2100 square inches had a relatively constant threat from birds greater than 4 pounds at approximately 5E-7 ingestions per aircraft departure. Reports from the manufacturers also showed that this size

of engine was more likely to ingest only portions of large birds, due to the much higher probability that an ingested bird may not enter the inlet on the engine centerline, and therefore would strike the inlet structure and be dismembered before reaching the engine rotor blades. This is further substantiated by the absence of reports of unsafe shutdown due to single large birds greater than 4 pounds for engines in this size range.

For engines larger than 2100 square inches, the rate of exposure to single large birds was observed to track roughly with increasing inlet size. The exposure rate for birds larger than 4 pounds for the large population of engines in the 2100-6000 square inch range was 1.5E-6 ingestions per aircraft departure. Review of the revenue service data however showed that medium and large turbofans exposed to single large birds above 4 pounds have demonstrated safe shutdown characteristics as defined under section 33.75 even with bird sizes up to 15 pounds. The rate of unsafe shutdown occurrences in accordance with section 33.75 criteria was approximately one event per 120 occurrences. This was attributed to the blade-out containment test requirements of section 33.94 constituting a more severe test relative to safe shutdown criteria for almost all engines.

The intent of the new rule is to establish the single large bird size as a function of inlet area greater than 2100 square inches at a level where the exposure to birds beyond that specified in this rule would be in the range of 1E-6 to 1E-7 ingestions per aircraft departure. This coupled with the prior service history record of satisfactory shutdown experience when exposed to very large birds, provides a potential improvement for hazardous consequences to continued safe flight into the extremely remote range of probability, i.e., 1E-7 to 1E-9.

The new rule conservatively established the single large bird requirement for engines in the 2100 -6000 square inch range at 6 pounds where the average exposure to larger birds was 8E-7 ingestions per aircraft departure. For engines greater than 6000 square inches the requirement was increased to 8 pounds to maintain an equivalent margin of safety.

The selection of the 200 knots ingestion speed for the large bird test was based on consideration of impact loading on the engine front stage blading. It was determined that for

most current turbine engine designs, conducting the test at 250 knots (maximum allowed airspeed below 10,000 feet altitude) would likely result in a relatively low blade impact vector, which results in less than maximum bird impact forces on the blade(s). This, coupled with the specified bird mass variations with engine inlet size, led to the decision to fix the ingestion speed at 200 knots, and perform an analysis to determine the critical spanwise target location for a particular engine application.

Large turbofan engines certified to the medium bird requirements of section 33.77 Amendment 6, which required bird velocities of 250 knots, sustained blade fractures and loss of power for ingested bird weights less than those demonstrated for certification test. Second generation turbofans certified under section 33.77 Amendment 10 rules which were in force during the 1980's used bird velocities which were equivalent to V2 speed for the application aircraft (160-180 knots for the large transports). While the in-service record was significantly improved, these engines were still experiencing blade fractures and power loss for bird weights less than the certification standard.

Engine ingestion parameters contributing to more than 50% power loss events were evaluated by AIA and AECMA. The most critical of the parameters evaluated which affected power loss were found to be bird weight, bird velocity, aiming point, and engine power setting. Each of these critical ingestion parameters have been evaluated in the proposed rule to determine the most severe conditions under which the medium bird test should be conducted.

The velocity to be used for the medium bird test was first established as the most critical velocity between V1 and 250 knots in order to cover the full range of takeoff and initial climb conditions that were considered to be potentially hazardous to the aircraft. In recognition of commuter and small business jet applications, the criterion was modified to reflect the fact that 250 knots was above the normal takeoff and climb speeds for this class of aircraft. A compromise criterion was chosen which required the medium bird ingestion velocity to be the most critical velocity between V1 and the velocity reached at 1500 feet above ground level (AGL).

Bird strike data for rotorcraft are not as comprehensive as that available for fixed wing aircraft, probably for a variety of reasons associated with reporting standards, forward speed, low altitude operations, and the extensive use of inlet protection or inherent installation shielding on rotorcraft. The following helicopter bird ingestion data has been reviewed in support of this rule: DGAC (France) 1983-1990; CAA (U.K.) 1976-1987 & 1989-1990; FAA (U.S.A.) 1985-1990; Transport Canada (Canada) 1981-1989; ICAO 1981-1989. The review showed reports of more than 600 bird strike events, but only four of these were reported as engine ingestions, and none of these were multiple events. Many of the 600 events involved flocks of small birds making engine ingestion very probable. Since there are no reports of significant power loss or mechanical damage it must be assumed that these ingestions had no effect on the engine.

It is concluded by the FAA that there are no records of any hazardous events or service difficulties associated with engine bird ingestion in multi-engine rotorcraft operation; and that to require a rotorcraft engine to demonstrate medium bird ingestion capability will impose an unnecessary burden upon the design while producing no measurable safety benefit. The FAA therefore proposes that engines intended for use in multi-engine rotorcraft need not show compliance with the medium bird ingestion requirements of this proposed rule.

With respect to the actual test day conditions where demonstrations are made, the proposal also considers the variability of engine performance as a function of changing ambient conditions. For example, substantial variations in engine rotor speed may take place between test demonstrations performed on cold days versus testing on hot days. These variations in rotor speed could in turn lead to variations in resulting damage, engine power, and operating characteristics. Even with no variation in blading damage, significant variations in power or other characteristics could be expected for conditions considerably different than for the test demonstration. Therefore, it was decided to allow the actual test day ambient conditions and engine pretest conditions to vary to permit equal flexibility among applicants, and to avoid conducting engine tests in unrepresentative conditions which could lead to cycle mismatches. However, each applicant must account for these potential variations by extrapolation to other

conditions specified in his type design. From the standpoint of power and operating characteristics, the applicant must show that the engine condition following the ingestion can be extrapolated to that specified in the type design. Therefore, it was determined that the sea level hot day corner point must be substantiated for both single large and flocking birds. It is believed that the hot day corner point case represents a worst case set of ambient conditions for which to substantiate bird ingestion capability. From the standpoint of potential limit exceedences, the applicant must consider the worst performing production engine that is allowed by the type design.

The current rules consider the possibility of imminent failure following a bird ingestion encounter producing damage. In consideration of this possibility, the rule recognizes the need to provide positive margin to demonstrate run-on capability and the ability for the engine to safely function throughout a conservative time for an emergency air-turn-back. This consideration includes recognition that the most critical encounters typically occur during heavy weight takeoffs, and may require dumping of fuel before returning to land. During this period it may be necessary to operate damaged engines throughout their operating cycle, including a need to make a go-around due to debris or equipment being on the runway. It is intent of this proposed rule to require the applicant to demonstrate the engine's ability to operate satisfactorily during such a circumstance. It is also recognized that it is not possible to extend this demonstration to include all possible conditions occurring throughout a flight, should the pilot decide to continue the flight to its destination. It was also judged that extended, but seemingly normal operation of multiple damaged engines was not likely to result in failure of multiple engines within the same flight. Lastly, considering the probable nature of bird ingestions, compliance with section 33.75 would not allow for a result which could lead to a hazardous failure as defined under that section. For these reasons, there is no requirement within this proposed rule to further consider imminent failure.

This proposed rule was also considered for harmonizing the part 33 and JAR-E, with respect to the maximum emergency rating which must be considered under this rule.

Consensus was achieved that there is no need to consider emergency ratings if it could be shown that the relative frequency of a bird ingestion event when using an emergency engine rating was less than 1E-8 . However, it was not possible to harmonize the part 33 and JAR-E in this regard since the part 33 does not define emergency ratings for turbofan engines.

Critical ingestion parameter tolerances were reviewed and supporting arguments made to justify the reasonableness of using a plus or minus 10 percent tolerance for variations within test parameters. The application of this tolerance was discussed in relationship to the intent to set the engine speed and thrust parameters to test-day takeoff conditions as described within the proposed rule, while the bird weight is expected to be controlled to "no less than" the weight specified within the rule. The expectations of achieving the bird aim points and impact speed within plus or minus 10 percent or its equivalent regarding aim point was compared against the general collective test experience. A sensitivity analysis was conducted to evaluate the expected effect on thrust or power, should there be first stage blade damage, for variations in test parameters up to 10 percent for the following parameters; engine speed, bird speed, target location, and bird weight. In general, these tolerances resulted in damage variations which produced approximately a 5 percent effect on thrust or power.

The harmonization working group determined that the current requirements of FAR 33.75 and JAR-E510 are not exactly the same and therefore, not fully harmonized. The FAR 33.75 requirements are restated as pass/fail criteria for the proposed medium and large bird ingestion tests. The bird ingestion requirements proposed by the JAA (NPA-E-20) includes a reference to JAR-E 510 for pass/fail criteria. However, that criteria is not the same as contained in this proposed rule. It is recognized that harmonization of Section 33.75 and JAR-E 510 is required, and will be addressed in future propulsion harmonization activities.

Disposition of Minority Position

The JAA has expressed disagreement with a portion of the proposal. The disagreement focuses on the degree of conservatism that the proposal offers with respect to certain flocking bird threats. The specific concern is that the proposed rule could potentially allow an engine to have

reduced operational capability after a 4 pound bird ingestion event than for an engine certified to the current rule. The authority also expressed concerns about the service history database, and the working groups determination of what level of flocking bird threat the proposal should address. The JAA minority position statement follows:

"The JAA expressed a dissenting opinion by requiring the new rules to include consideration of the threat which is created by flocking birds larger than 2.5 lb. The JAA proposed, in the draft new rules, the imposition of an additional requirement for each engine having an inlet area of 2100 square-inches or more. The applicant would be required to establish that when the fan assembly of such an engine is subjected to the ingestion of a single bird weighing at least 4 lb., under the same ingestion conditions as prescribed for the 6 lb. or 8 lb. bird ingestion test, the fan assembly retains sufficient integrity to demonstrate a total imbalance level less than 12% of the imbalance level corresponding to the loss of one complete fan blade airfoil.

The JAA rationale is as follows:

- The stated aims of the draft new rules include reducing the risk of a dual engine power loss, the improvement goal being approximately 1E-8 or better per aircraft departure, and substantiation of that goal. The preamble also states that "unless the rule addresses the actual in-service bird threat, there can be no assurance that future designs would continue to exhibit acceptable capability". Allowing fan blades to be shown, during certification, as being less capable to withstand some sizes of birds than current in-service designs is not compatible with those stated aims.

- The draft new rules (without the addition proposed by JAA) retain the same acceptance criteria for single large bird ingestion standard as in the existing rules. Extensive damage leading either to an immediate shutdown or necessitating a shutdown after 15 seconds is permitted, the only limit to the severity of the damage to the fan being safe containment, safe loads and no fire. However, in practice there are very good reasons for the manufacturers to establish that, with respect to containment, loads, fire, etc., the damage is not more severe than occurs with a full fan blade release. That practice is recognized in the draft new rules by a provision for waiving a full

engine test demonstration of compliance with the large bird ingestion standard if it can be demonstrated that compliance with the requirements for containment of a full fan blade is a more severe demonstration.

- Thus, because the minimum design allowed by the draft new rules is actually set primarily by the blade containment requirements, the large bird is allowed to cause extensive damage equivalent to that which results from the release of one entire fan blade. The increase of the weight of the large bird in the draft new rules, from 4 lb. to 6 lb. or 8 lb., will not improve the safety level if engines are designed to the minimum allowed by those new rules because it is a lower minimum that was demonstrated during certification of many, possibly most, of the current in-service engines. Further, it does not automatically follow that designing for a "safe" shutdown with a 6 lb. or 8 lb. bird results in a higher safety level than designing for a "safe" shutdown with a 4 lb. bird.

- The certification tests on most of the types of large engines currently in service demonstrated that the 4 lb. bird certification ingestion test did not result in extensive damage to their fan blades. Therefore, the service experience which is the basis for the aims of the draft new rules is derived mainly from engines which were better during certification than required by the existing rules and better than can be allowed under the draft new rules without the JAA proposed addition.

- The draft new rules require the large engines to retain a run-on and a 75% thrust capability when subjected to a multiple 2.5 lb. bird ingestion test but, as mentioned previously, the 6 lb. or 8 lb. bird ingestion is allowed to result in such extensive fan damage as to necessitate an immediate shutdown. In this case no information would then be available on the behavior of the fan in the event of a 4 lb. bird ingestion because the draft new rules do not address either medium (flocking) birds heavier than 2.5 lb. or large birds lighter than 6 lb. or 8 lb.. The ingestion of a 4 lb. bird could, with some fan designs, also result in an immediate unavoidable engine shutdown.

- There is already an example of a new engine which complies with the draft new rules for 2.5 lb. and 8 lb. bird ingestion's but the 8 lb. bird was shown to cause extensive damage commensurate with an immediate unavoidable shutdown. It would not have been possible, from only that damage, to make any reasonable assessment of what damage would have resulted from a 4 lb. large bird certification test. Economic pressure could lead to an increased use of fan blades which are designed to the minimum allowed by the draft new rules because it provides an opportunity to reduce the weight of the fan blades, disc and containment ring.
- Allowing new fan designs to be less capable than current in-service designs to withstand the ingestion of a 4 lb. bird would not be a concern if the multi-engine ingestion threat did not include birds weighing up to, and more than, 4 lb.. However, the service experience supporting the draft new rules shows that the multiple engine ingestion rate for birds larger than 2.5 lb. is greater than 1E-7. With current in-service engines these events have resulted in a marginally acceptable risk of multi-engine shutdown. If no certification data is available to show that new designs are equal to, or better than, current designs at withstanding those birds, it must be assumed that such encounters will result in unavoidable multi-engine shutdowns at a rate of roughly 1E-7 which is in excess of the declared aim of 1E-8. The JAA proposed additional requirement is intended to provide such certification data.
- All parties involved in the development of the draft new rules recognize that flocking birds larger than 2.5 lb. may be encountered and the JAA does not disagree totally with the position that mitigation of this risk to 1E-8 or better per airplane departure cannot be economically provided entirely by available engine technology. However, the JAA believes that future engine fan technology must not be allowed to be less capable at mitigating that risk than current in-service engines.
- Consequently the JAA concluded that the draft new rules are not achieving the stated aims by an amount that is more than necessary and not ensuring an achievable retention or improvement to the safety level by not ensuring that new fan designs are equal to, or better than, current designs at retaining their integrity when subjected to the ingestion of a 4 lb. bird under the

conditions applicable to large bird ingestion requirements. The additional 4 lb. bird consideration proposed by JAA is intended to do no more than to provide some assurance of parity with current in-service fan designs, it is not intended to ensure a full run-on capability after the ingestion of a 4 lb. bird. “

The remaining EHWG members have reviewed the JAA position statement, and offer the following comments:

The JAA Position Statement above contains two major concerns; (1) that flocking birds larger than 2.5 lb. are a significant enough threat to require an evaluation for run-on capability; and (2) that the proposed rule may allow a lesser capable engine than those certified to the current rule with respect to medium flocking and single large bird ingestion.

With respect to JAA’s first major concern:

The majority of EHWG members believe the proposed rule adequately addresses the flocking bird threat within the stated goal of this rulemaking. That improvement goal is to reduce the risk of a dual engine power or thrust loss greater than fifty percent (50%) from current in-service rates, to approximately 1E-8 or better per aircraft departure.

The worldwide bird ingestion threat database used for the medium and large engine portion of this rulemaking includes substantial data from 1970 through 1995, and encompasses approximately 85 million aircraft flights. The database includes data for engine models with fan inlet diameters from 60” to 100”. This database shows the rate of multi-engine ingestions of birds larger than 2.5 lb. to be approximately 1E-7 per aircraft departure. The probability of a dual engine shutdown is predicted to be approximately 1E-8 per aircraft departure. This probability is based on the observed multi-engine ingestion rate and demonstrated rate of engine shutdown for ingestion of birds in this size range. The above rates/probabilities are for engines certified to the current 1.5 lb. medium flocking and 4 lb. single large bird standards which are less severe than the proposed rule.

The JAA Position Statement notes that the dual engine power loss/shutdown rate is marginally acceptable today. The proposed rule requires 2.5 lb. medium flocking and 6-8 lb.

(function of inlet size) large single birds which are more severe demonstrations, and which the majority of EHWG members believe can only improve the overall world fleet ingestion capability of engines certified thereto. This is especially true when considering the additional run-on requirements of the proposed medium bird test. Therefore, the majority of EHWG members do not believe that additional run-on evaluation requirements for flocking birds larger than 2.5 lb. is necessary.

With respect to JAA's second major concern:

Concerning medium flocking birds, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 1.5 lb. bird requirement for 5 minutes of run-on. The proposed rule is for a 2.5 lb. bird with a 20 minute run-on requirement. This is obviously a much more severe design and test requirement than for engines certified to the current rule, and should yield a more capable engine, not a less capable one. This is supported by a test that is run to worst case conditions of fan speed, target location, number of birds, and new run-on profile. In the original review of historical data used in consideration of the development of the proposed rule, it was noted that single large birds (greater than 2.5 lb.) resulted in significant powerloss about 50% of the time, mostly due to mechanical damage to the fan. It is difficult to see how an argument could be made that these earlier certified engines have a greater capability than that demonstrated by a minimum engine that passes both the 2.5 lb. medium flocking run-on and 6-8 lb. single large bird safe shutdown tests.

With respect to single large birds, the current marginally acceptable dual engine power loss rate relates primarily to engines certified to a 4 lb. single large bird safe shutdown requirement. With identical test criteria, it can only be expected that an engine passing the proposed test will be at least as capable of a large bird safe shutdown as a current engine. Engine models that are tested using these larger birds will have greater axial loads and greater local stresses on the impacted blades than for the 4 lb. requirement. Therefore, the blades must have greater capability with respect to a safe shutdown criteria. The majority of EHWG members do not believe the proposed large bird criteria allows sufficient latitude such that an engine can pass

a 6-8 lb. test but not a 4 lb. test. The NPRM has not altered the current objective of a safe shutdown after a large bird ingestion.

The JAA Position Statement also argues another point they consider significant to this rulemaking: That economic pressures could reduce the margin above the stated pass/fail criteria that engines may be designed for, and therefore result in less costly and less capable new designs of reduced margin when compared to engines currently in service. The majority of EHWG members do not believe it is appropriate to consider the margin with which any particular engine model demonstrates compliance, and that discussion of economic pressure has no place in objective evaluations of safety. The purpose of the rule is to set forth minimum requirements below which it is considered unsafe. Everything that meets the minimum is considered safe. In other words, either the regulatory criteria is appropriate, or it is not. Margin is not an issue for properly chosen criteria. The majority of EHWG members consider the proposed rule criteria as appropriate, and therefore demonstrated margin above that criteria is not necessary. With respect to engines certified to the current 4 lb. single large bird safe shutdown test standard, some fan designs have exhibited blade fragmentation during the test while others have not. It is incorrect, however, to infer continued run-on capability simply from lack of fan blade fragmentation during the 15 second "hands-off" period of the large bird test. Secondary damage and operability effects of continued high power operation with mechanical and/or aerodynamic unbalance would have to be taken into consideration. It is also true that previously certified designs which have experienced fan blade fragmentation in large bird tests have accumulated well over 50 million hours in revenue service with a satisfactory bird ingestion record. The fact that these engine designs, certified to the current standard, have continued to operate and produce greater than 50% thrust in a significant percentage of revenue service large bird ingestion events, is attributable more to the combination of ingestion conditions being less severe than the certification test than the robustness of the fan design. The majority of the EHWG conclude this same mixed result will continue to occur in the single large bird certification test. It is also concluded that such mixed results relative to fan blade fragmentation are not significant relative

to this rulemaking effort's stated goal of improving the world fleet rate of dual engine power loss.

The majority of EHWG members also do not agree with the JAA statement that the proposed rule has a lower design minimum than the current rule, and believe that the proposed rule significantly increases the certification standards for medium and large bird ingestion by increased severity of bird size, run-on, and target location. The test criteria of the current rule is less severe than that specified for under the proposed rule, therefore, it can not be described as providing "greater margin" when compared to a marginally compliant engine under the proposed rule. Furthermore, no evidence has been offered to demonstrate that engines certified under the current rule would always have margin for run-on following the ingestion of a 4 lb. flocking bird. Thus, the arguments of current vs. proposed are considered subjective and unproven as indicators of future performance in service.

Consequently, for the reasons stated above, the majority of EHWG members have concluded that evaluation of run-on capability for birds larger than 2.5 lb. is not necessary to meet the stated rulemaking objective, and therefore the JAA proposal does not need to be incorporated into the proposed rule.

General Discussion of the Proposals

Section 23.903 (a)(2) and 25.903 (a)(2)

This proposal revises the part 23 and part 25 requirements associated with foreign object ingestion into turbine engines to be consistent with the proposed part 33 changes.

Section 33.76.

Proposed new section 33.76 would contain the bird ingestion requirements. Bird ingestion standards are currently found in section 33.77. This proposal was developed by the engine harmonization working group, and contains substantial common language that will be reflected both in Part 33 and JAR-E. The only significant difference between Part 33 and JAR-E is an additional large bird ingestion

criteria in JAR-E (JAR-E 800 (b)(5) as proposed by JAA P NPA-E-20, dated 12 July 1996). Also, the proposed new section adopts the approximate metric equivalents for certain test parameters to further commonality between Part 33 and JAR-E.

Section 33.77.

This proposal would remove the bird ingestion standards now specified in section 33.77 (a) and (b); these new proposed bird ingestion standards would appear in a new section 33.76. Paragraphs (a ) and (b) will be held in reserved. Paragraphs (d) and (e) have been revised to eliminate any reference paragraphs to (a) and (b).

Paperwork Reduction Act

In accordance with the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.), there are no record keeping or reporting requirements associated with this proposed rule.

Regulatory Evaluation Summary

.....(FAA to Provide).....

International Trade Impact Analysis

.....(FAA to Provide).....

Regulatory Flexibility Determination

.....(FAA to Provide).....

Federalism Implications

The regulations proposed herein would not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 12612, it is determined that this proposal would not have sufficient federalism implications to warrant the preparation of a Federalism Assessment.

Conclusion

For the reasons discussed above, including the findings in the Regulatory Determination and the International Trade Impact Analysis, the FAA has determined that this proposed regulation is not a significant regulatory action under Executive Order 12866. In addition, the FAA certifies that this proposal, if adopted, will not have a significant economic impact, positive or negative, on a substantial number of small entities under the criteria of the Regulatory Flexibility Act. This proposal is considered significant under DOT Regulatory Policies and Procedures (44 FR 11034, February 26, 1979). An initial regulatory evaluation of the proposal, including a Regulatory Flexibility Determination and Trade Impact Analysis, has been placed in the docket. A copy may be obtained by contacting the person identified under "FOR FURTHER INFORMATION CONTACT."

List of Subjects in 14 CFR Part 33

Air transportation, Aircraft, Aviation safety, Safety.

The Proposed Amendment

In consideration of the foregoing, the Federal Aviation Administration proposes to amend Parts 23, 25 and 33 of the Federal Aviation Regulations (14 CFR Part 23, 25, 33) as follows:

PART 23- AIRWORTHINESS STANDARDS: NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

1. The authority citation for Part 23 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704

2. Section 23.903 is amended by revising paragraph (a)(2) to read as follows:

***ξ 23.903 Engines***

* * * * *

***(a) ******

(2) Each turbine engine and its installation must either -

(i) Comply with section 33.77 and 33.76 of this chapter in effect on

[**Insert effective date of final rule**], or as subsequently amended; or

(ii) Comply with section 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to [**Insert effective date of final rule**]; unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iii) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

3. The authority citation for Part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704

4. Section 25.903 is amended by revising paragraph (a)(2) to read as follows:

***ξ 25.903 Engines***

* * * * *

***(a) ******

(2) Each turbine engine must either -

(i) Comply with section 33.77 and 33.76 of this chapter in effect on [**Insert effective date of final rule**], or as subsequently amended; or

(ii) Comply with section 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to [**Insert effective date of final rule**]; unless that engine's foreign object ingestion service history has resulted in an unsafe condition; or

(iii) Be shown to have a foreign object ingestion history in similar installation locations which has not resulted in any unsafe condition.

* * * * *

PART 33 - AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

5. The authority citation for Part 33 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704

6. Section 33.76 is added to Subpart E, to read as follows

§ 33.76 Bird Ingestion.

(a) General. Compliance with paragraphs (b) and (c) of this section shall be in accordance with the following:

(1) All ingestion tests shall be conducted with the engine stabilized at no less than 100 percent takeoff power or thrust, for test-day ambient conditions prior to the ingestion. In addition, the demonstration of compliance must account for engine operation at sea-level takeoff conditions on the hottest day that a minimum engine can achieve maximum rated takeoff thrust or power.

(2) The "engine inlet area" as used in this section to determine the bird quantity and weights will be established by the applicant and identified as a limitation on the inlet throat area in the installation instructions required under section 33.5.

- (3) The impact to the front of the engine from the single large bird and the single largest medium bird which can enter the inlet must be evaluated. It must be shown that the associated components when struck under the conditions prescribed in paragraphs (b) or (c) of this section, as applicable, will not affect the engine to the extent that it cannot comply with the requirements of paragraphs (b)(3) and (c )(6) of this section.

(4) For an engine that incorporates an inlet protection device, compliance with section 33.76 shall be established with

the device functioning. The engine approval will be endorsed to show that compliance with the requirements has been established with the device functioning.

(5) Objects that are acceptable to the Administrator may be substituted for birds when conducting the bird ingestion tests required by paragraphs (b) and (c) of this section.

(6) If compliance with the requirements of this section is not established, the engine type certification documentation will show that the engine shall be limited to aircraft installations in which it is shown that a bird cannot strike the engine, or be ingested into the engine, or adversely restrict airflow into the engine.

(b) Large birds. Compliance with the large bird ingestion requirements shall be in accordance with the following:

(1) The large bird ingestion test shall be conducted using one bird of a weight determined from Table 1 aimed at the most critical exposed location on the first stage rotor blades and ingested at a bird speed of 200 knots for engines to be installed on airplanes, or the maximum airspeed for normal rotorcraft flight operations for engines to be installed on rotorcraft.

(2) Power lever movement is not permitted within 15 seconds following ingestion of the large bird.

(3) Ingestion of a single large bird tested under the conditions prescribed in this section may not cause the engine to:

(i) catch fire;

(ii) release hazardous fragments through the engine casing;

(iii) generate loads greater than those ultimate loads specified under Section 33.23(a); or

(iv) lose the ability to be shut down.

(4) Compliance with the large bird ingestion test requirements of this paragraph may be waived if it can be demonstrated that the containment requirements of section 33.94(a) constitutes a more severe demonstration than the requirements of section 33.76(b).

Table 1
Large Bird Weight Requirements

| Engine Inlet Area (A) square meters (square inches) | Bird Weight kg. (lb.) |
|---|---|
| 1.35 (2,092)> A | 1.9 (4.2) minimum, unless a smaller bird is determined to be a more severe demonstration. |
| 1.35 (2,092)≤ A< 3.90 (6,045) | 2.8 (6.2) |
| 3.90 (6,045)≤ A | 3.7 (8.2) |

(c) Small and Medium birds. Compliance with the small and medium bird ingestion requirements shall be in accordance with the following:

(1) Analysis or component test, or both, acceptable to the Administrator, shall be conducted to determine the critical ingestion parameters affecting power loss and damage**.** Critical ingestion parameters shall include, but are not limited to, the effects of bird speed, critical target location, and first stage rotor speed. The critical bird ingestion speed should reflect the most critical condition within the range of airspeeds used for normal flight operations up to 1500 feet above ground level, but not less than $V_1$ minimum for airplanes.

(2) Medium bird engine tests shall be conducted so as to simulate a flock encounter, and will use the bird weights and quantities specified in Table 2. When only one bird is specified, that bird will be aimed at the engine core primary flow path; the other critical locations on the engine face area must be addressed, as necessary, by appropriate tests or analysis or both. When two or more birds are specified in Table 2, the largest of those birds must be aimed at the engine core primary flow path, and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the engine face area.

(3) In addition, except for rotorcraft engines, it must also be substantiated by appropriate tests or analysis or both, that when the full fan assembly is subjected to the quantity and weights of birds from Table 3, that the engine can comply with the acceptance criteria of FAR 33.76(c).

(4) A small bird ingestion test is not required if the prescribed number of medium birds pass into the engine rotor blades during the medium bird test.

(5) Small bird ingestion tests shall be conducted so as to simulate a flock

encounter using one 85 gram (0.187 lb.) bird for each 0.032 square meters (49.6 square inches) of inlet area, or fraction thereof, up to a maximum of 16 birds. The birds will be aimed so as to account for any critical exposed locations on the first stage rotor blades, with any remaining birds evenly distributed over the engine face area.

(6) Ingestion of small and medium birds tested under the conditions prescribed in paragraph (c) of this section may not cause:

(i) more than a sustained 25 percent power or thrust loss;

(ii) the engine to be shut down during the required run-on demonstration prescribed in paragraphs (c)(7) or (c)(8) of this section;

(iii) the conditions defined in paragraphs (b)(3) of this section.

(iv) unacceptable deterioration of engine handling characteristics.

(7) Except for rotorcraft engines, the following test schedule shall be used:

(i) ingestion so as to simulate a flock encounter, with approximately 1 second elapsed time from the moment of the first bird ingestion to the last.

(ii) followed by 2 minutes without power lever movement after the ingestion.

(iii) followed by 3 minutes at 75 percent of the test condition.

(iv) followed by 6 minutes at 60 percent of the test condition.

(v) followed by 6 minutes at 40 percent of the test condition.

(vi) followed by 1 minute at approach idle.

(vii) followed by 2 minutes at 75 percent of the test condition.

(viii) followed by stabilizing at idle and engine shut down.

The duration specified are times at the defined conditions with the power lever being moved between each condition in less than 10 seconds.

(8) For rotorcraft engines, the following test schedule shall be used:

(i) Ingestion so as to simulate a flock encounter within approximately 1 second elapsed time between the first ingestion and the last.

(ii) followed by 3 minutes at 75 percent the test condition.

(iii) followed by 90 seconds at descent flight idle.

(iv) followed by 30 seconds at 75 percent of the test condition.

(v) followed by stabilizing at idle and engine shut down.

The duration specified are times at the defined conditions with the power being changed between each condition in less than 10 seconds.

(9) Engines intended for use in multi-engine rotorcraft are not required to comply with the medium bird ingestion portion of this section, providing that the appropriate type certificate documentation is so endorsed.

(10) If any engine operating limit(s) is exceeded during the initial 2 minutes without power lever movement [reference section 33.76(c)(7)(ii)], then it shall be established that the limit exceedance(s) will not result in an unsafe condition.

Table 2
Medium Flocking Bird Weight & Quantity Requirements

| Engine Inlet Area (A) square meters(square inches) | Bird Quantity | Bird Weight kg.(lb.) |
|---|---|---|
| 0.05 (77.5)> A | none | ------ |
| 0.05 (77.5)≤ A < 0.10 (155) | 1 | 0.35 (0.77) |
| 0.10 (155)≤ A < 0.20(310) | 1 | 0.45 (0.99) |
| 0.20 (310)≤ A < 0.40 (620) | 2 | 0.45 (0.99) |
| 0.40 (620)≤ A < 0.60 (930) | 2 | 0.70 (1.54) |
| 0.60 (930)≤ A < 1.00 (1,550) | 3 | 0.70 (1.54) |
| 1.00 (1,550)≤ A < 1.35 (2,092) | 4 | 0.70 (1.54) |
| 1.35 (2,092)≤ A < 1.70 (2,635) | 1<br>plus 3 | 1.2 (2.65)<br>0.70 (1.54) |
| 1.70 (2,635)≤ A < 2.10 (3,255) | 1<br>plus 4 | 1.2 (2.65)<br>0.70 (1.54) |
| 2.10 (3,255)≤ A < 2.50 (3,875) | 1<br>plus 5 | 1.2 (2.65)<br>0.70 (1.54) |
| 2.50 (3,875)≤ A < 3.90 (6045) | 1<br>plus 6 | 1.2 (2.65)<br>0.70 (1.54) |
| 3.90 (6045)≤ A < 4.50 (6975)3 | 3 | 1.2 (2.65) |
| 4.50 (6975)≤ A | 4 | 1.2 (2.65) |

Table 3
Additional Integrity Assessment

| Engine Inlet Area (A) square meters(square inches) | Bird Quantity | Bird Weight kg.(lb.) |
|---|---|---|
| 1.35 (2,092)> A | none | ------ |
| 1.35 (2,092)≤ A < 2.90 (4,495) | 1 | 1.2 (2.65) |
| 2.90 (4,495)≤ A < 3.90 (6,045) | 2 | 1.2 (2.65) |
| 3.90 (6,045)≤ A | 1 | 1.2 (2.65) |
| | plus 6 | 0.70 (1.54) |

7. Section 33.77 is amended by revising paragraphs (d) (3) and (e) to read as follows:

***ξ 33.77 Foreign object ingestion***

* * * *

(a) Reserved

(b) Reserved

(d) *** (3) The foreign object, or objects, stopped by the protective device will not obstruct the flow of induction air into the engine with a resultant sustained reduction in power or thrust greater than those values required by paragraph (c) of this section.

(e) Compliance with paragraph (c) of this section must be shown by engine test under the following ingestion conditions:

| Foreign object | Test quantity | Speed of foreign objec | Engine operation | Ingestion |
|---|---|---|---|---|
| | | | | |
| Ice..... | Maximum accumulation on a typical inlet cowl and engine fa resulting from a 2-minute dela in actuating anti-icing system, or a slab of ice which is com-parable in weight or thickness for that size engine. | Sucked in..... | Maximum cruise... | To simulate a continuous maximum icing encounter at 25 degrees F. |
| Hail (0.8 to 0.9 specific gravity | For all engines: With inlet are of not more than 100 square inches: one 1-inch hailstone. With inlet area of more than 1( square inches: one 1-inch and one 2-inch hailstone for each 1 square inches of inlet area or fraction thereof. | Rough air flight speed of typical aircraft. | Maximum cruise a 15,000 feet altitude | In a volley to simulate a hailstone encounter. One-half the number of hail-stones aimed at random are over the face of the inlet an the other half aimed at the critical face area. |
| | For supersonic engines (in add tion): 3 hailstones each having a diameter equal to that in a straight line variation from 1 inch at 35,000 feet to 1/4 inch at 60,000 feet using diameter corresponding to the lowest supersonic cruise altitude expected. | Supersonic cruise velocity, Alternatively use subsonic velocitie with larger hailstones give equivalent kineti energy. | Maximum cruise... | Aimed at critical engine fac area. |
| Water..... | At least 4 percent of engine air flow by weight. | Sucked in..... | Flight idle, accel-eration, takeoff, deceleration. | For 3 minutes each at idle and takeoff, and during acceleration and deceleration in spray to simulate rain. |

Note. - The term "inlet area" as used in this section means the engine inlet projected area at the front face of the
It includes the projected area of any spinner or bullet nose that is provided.

Issued in Washington, DC, on

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# BIRD INGESTION RULE
# ADVISORY MATERIAL
# DRAFT

NOTE: It is intended that this advisory material will replace the current material on bird ingestion requirements located in AC33.2.

(1) General:

(a) The front of the engine is defined as any part of the engine which can be struck by a bird. This includes, but is not limited to, the following components, nose cone, spinner (centerbody) on the fan or compressor rotor, engine inlet guide vane assemblies, and any engine protection device. Ingestion is defined as the passage of a bird into the rotating blades.

The applicant should assess the bird impact to components at the front of the engine relative to the critical parameters of the component. For example, the ability of the spinner to withstand a bird impact should be assessed for the most critical parameters of the spinner, which would include; bird size, bird velocity, target location , and spinner rotational speed.

(b) Artificial birds or devices which simulate the mass, shape, and density of birds, and which are acceptable to the Administrator, may be used for the ingestion tests.

(c) For substantiating derivative engine models , the engine tests should be performed under the conditions of section 33.76, unless alternative equivalent demonstration evidence, acceptable to the Administrator, is provided. This substantiation evidence may come from the applicant's experience on engines of comparable size, design, construction, performance, and handling characteristics, obtained during development, certification or operation. Any parametric analysis used to substantiate derivative engines should fall within 10% variation in the critical impact parameters used to substantiate the original engine certification basis.

(d) In conducting the analysis or component tests, or both, to determine the critical ingestion parameters, the applicant should consider related

experience for the type and size of engine being evaluated, with particular attention to the types and causes of failures in that related experience.

(e) Engine tests should be conducted with a fully operational engine which is representative of the Type Design. The normal functioning of any automatic systems not requiring pilot intervention is acceptable (including automatic power lever movement), provided that a time limited dispatch (TLD) or similar analysis acceptable to the Administrator is submitted. Automatic systems may be required for dispatch if a suitable analysis is not provided. The Applicant may also conduct the test(s) with any automatic systems in a functionally degraded state, if this does not constitute a less severe test.

(f) The object of the test is to cover all the defined impact zones. The test facility should be appropriately calibrated to ensure that the controlling parameters defined by the analysis of the critical conditions (e.g. bird speed, aiming locations) are within an acceptable tolerance. This tolerance band should be derived from an analysis of the sensitivity of the critical impact parameter to variations in the controlling parameters. The band should be such that variations in the critical impact parameter are not more than 10% resulting from any combination of the controlling parameters.

Certain test facilities and installations may affect or reduce the stability margin of the engine due to airflow distortion attributed to the close proximity bird gun(s) to the engine inlet. These effects must be identified prior to the test.

(g) If turboprop or turboshaft engines are tested using an alternative load device which could induce different engine response characteristics than when the engine is coupled with a propeller or installed in the aircraft, the interface with the test facility, other aircraft or propeller systems should be monitored during the test and should be used for determining how the engine would respond in a representative installation and for ensuring that the engine would then comply with the requirements.

Input and output data across the engine interfaces with the aircraft systems should be provided by the engine manufacturer in the installation manual regarding the expected interaction of the engine with these systems during ingestion events. Of particular interest would be dynamic interactions such as auto surge recovery, propeller auto feather.

(h) For the purpose of FAR 33.76, a minimum engine is defined as a new engine that exhibits the type design's most limiting operating parameter(s), with respect to the bird ingestion conditions prescribed in this section. These operating parameters include, but are not limited to, power or thrust, turbine temperature, and rotor speed.

(i) The term "first stage rotating blades" includes the first of the exposed stages of any fan or compressor rotor which are susceptable to a bird strike or bird ingestion. These first stage rotating blades are considered to be part of the front of the engine, as defined in paragraph (1)(a) above. This definition encompasses ducted, unducted and aft fan engine designs. In these latter cases, blading on multiple rotors (i.e., primary and secondary airflow paths) should be considered separately when complying with section 33.76.

(2) Large bird:

(a) For the purpose of the section 33.76 test, the complete loss of engine power or thrust after ingestion will be accepted.

(b) The most critical location on the first stage rotating blades may be determined from analysis or component tests, or both. Determination of the most critical location to be considered in 2 (c) above should include evidence, where necessary, on:

(i) the effect of the bird strike on rotating ~~and static~~ components,
(ii) the compressor casing strength,
(iii) the possibility of multiple blade failures,
(iv) the strength of the engine structure and main shafts relative to the unbalance and excessive torque likely to occur.

(c) When compliance with the containment requirements of section 33.94(a) is used in lieu of the large bird ingestion test, the determination that the 33.94(a) test constitutes a more severe demonstration should consider the engine dynamic response to a large bird ingestion event, and include, but not be limited to, the effects of engine unbalance loads, engine torque loads, surge related loads, and axial loads, resulting from the bird impact which are transmitted to the front of the engine.

(3) Small and medium birds:

(a) The Applicant will identify the critical target locations for the small and medium bird ingestion tests required by section 33.76(c), and appropriately consider potential effects of assumed installations in aircraft. After targeting one bird for the most critical exposed location, applicants should target any remaining birds in proportion to the fan face area, including the centerbody if applicable, to achieve an even distribution of birds over the face of the engine. The even distribution of remaining birds should also include consideration of any additional critical locations. Any critical locations not targeted may be evaluated separately by analysis or component testing, or both.

(b) In the tests performed under section 33.76(c), the engine is required to produce at least 75% of takeoff power or thrust after ingestion of small and medium birds. Nevertheless, a momentary power or thrust drop below this value may be acceptable as long as its duration does not typically not exceed 3 seconds.

(c) The purpose of the sea-level hot day corner point assessment under 33.76(a)(1) is to address both the basis for loss of performance margins (exhaust gas temperature, measured gas temperature, etc.) and also the influence on available power or thrust of engine control system limiters or controlling parameters at a common critical hot day break point condition. This post test analysis approach permits conduct of tests at takeoff power or thrust for actual test day conditions and provides a uniform assessment of power loss against rated levels independent of the actual tests ambient conditions.

(d) Any analysis used in place of a fan rig or engine test for demonstrating compliance with section 33.76 should be substantiated by evidence based on tests and should have demonstrated its capability to predict full fan rig or engine tests results.

(e) Rig tests may be used to determine if a particular bird size will pass through the inlet and into the rotor blades.

(f) Thrust or power should be measured by a means which can be shown to be accurate throughout the test to enable the thrust or power to be set without undue delay and maintained to within plus or minus 3 percent of the specified levels.

If a sustained high vibration condition exists after the first 2 minutes of operation after the bird ingestion, then thrust or power may be varied as a protective measure within plus or minus 3 percent of the specified levels. Alternative load devices of some test facilities such as waterbrakes, may be unable to control power within the plus or minus 3% tolerance. This should be identified and approved prior to the test.

(g) Exceedences of engine operating limits are not expected to occur. However, exceedances may be permitted to occur only during the first 2 minutes [reference section 33.76(c)(7)(ii)] following the ingestion of the birds in the 20 minute run-on test. Any limit exceedence(s) should be recorded, and it must be shown by evidence acceptable to the Administrator, that the limit exceedance(s) will not result in an unsafe condition [reference 33.76(c)(10)]. This evidence may come from previous test or service experience, or analysis thereof. Also, under such circumstances, the operating instructions, installation manual, and maintenance manual should be reviewed to assure that appropriate instructions are included within those documents, and that any such instructions are appropriately validated.

FAA Action: (1) Airworthiness Standards; Bird Ingestion; NPRM -- FAA-1998-4815 and
(2) Final rule -- FAA-1998-4815

(3) Advisory Circular; Bird Ingestion Certification Standards 33.76-1 – Regulatory and Guidance Library